UNITED STATES DEPARTMENT OF THE INTERIOR, OSCAR L. CHAPMAN, *Secretary*
FISH AND WILDLIFE SERVICE, ALBERT M. DAY, *Director*

JUVENILE FORMS OF *NEOTHUNNUS MACROPTERUS, KATSUWONUS PELAMIS* AND *EUTHYNNUS YAITO* FROM PHILIPPINE SEAS

By CHARLES B. WADE, Aquatic Biologist

Illustrations by Pablo Bravo

FISHERY BULLETIN 53

From Fishery Bulletin of the Fish and Wildlife Service

VOLUME 51

UNITED STATES GOVERNMENT PRINTING OFFICE WASHINGTON : 1950

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 15 cents

ABSTRACT

Almost nothing was known concerning the life histories of Philippine tunas prior to the inception of the Philippine Fishery Program of the Fish and Wildlife Service. In this paper are recorded biological data and observations on juvenile forms of three species of Philippine tuna: *Neothunnus macropterus*, *Katsuwonus pelamis*, and *Euthynnus yaito*. The juveniles of two of these species are compared with the young of the same species taken by Schaefer and Marr (1948a; 1948b) in the eastern Pacific, and the third species with a similar species from that area. Probable spawning areas for all three species have been determined in several localities in the Philippines.

CONTENTS

	Page
Neothunnus macropterus (Temminck and Schlegel)	395
Katsuwonus pelamis (Linnaeus)	399
Euthynnus yaito (Kishinouye)	400
Spawning areas	403
Summary	404
Literature cited	404

JUVENILE FORMS OF *NEOTHUNNUS MACROPTERUS, KATSUWONUS PELAMIS,* AND *EUTHYNNUS YAITO* FROM PHILIPPINE SEAS

By CHARLES B. WADE, *Aquatic Biologist*

The juvenile forms of the various species of tuna inhabiting the Pacific Ocean are but little known. Schaefer and Marr (1948a; 1948b) were the first investigators to publish definite information regarding the young of the yellowfin tuna, skipjack or striped tuna, bonito, and frigate mackerel. Their data were secured from material taken off the west coast of Central America. Marr (1948) also recorded several specimens of juvenile *Katsuwonus*, striped tuna or skipjack, from the northern Marshall Islands. In 1880 Lütken recorded two juvenile specimens considered by later authors as perhaps *Neothunnus*, yellowfin tuna: one from an unspecified location, probably the East Indies, and the other from the South China Sea. The young of several tuna-like fishes from Japanese waters were discussed in a general way by Kishinouye (1923). Other than these, there are no references available on the juveniles of these important Pacific species.

Small but representative collections of the juvenile forms of *Neothunnus macropterus*, yellowfin tuna; *Katsuwonus pelamis*, skipjack or striped tuna; and *Euthynnus yaito*, bonito, have been made by the pelagic fish-studies section of the Philippine Fishery Program of the Fish and Wildlife Service,[1] as part of its studies on these commercially important fish. The specimens were secured by night-light operations [2] and market collecting. Night lights were used at every opportunity for more than a year aboard the Program's research vessel *Spencer F. Baird* under a wide variety of enviromental conditions ranging from secluded bays to the high seas. In addition to the use of the night light, the public markets were searched for small, tuna-like fishes. Two genera, *Euthynnus* and *Auxis*, were found principally in the markets, and *Neothunnus* and *Katsuwonus* were taken only by night light.

[1] A part of the Philippine Rehabilitation Program authorized by the Philippine Rehabilitation Act of 1946, title 50, App. U. S. Code, Sec. 1789.

[2] At night, while the vessel is lying at anchor or hove to on a hydrographic station, an electric light is suspended beneath the surface of the water and the fishes and other organisms attracted by it are collected with dip nets.

868606°—50

Counts were made of the vertebrae of one or two specimens of each species. These specimens were cleared and stained in alizarin red S using Hollister's (1934) method of preparing the material. The fork length, which is measured from the tip of the snout to the end of the median caudal rays, is used as the length of the specimens throughout this paper.

NEOTHUNNUS MACROPTERUS (TEMMINCK AND SCHLEGEL)

Eighteen juvenile tuna, assigned to *Neothunnus macropterus*, were collected by the biologists of the Philippine Fishery Program aboard the research vessel *Spencer F. Baird.* They are identical with the specimens described as *N. macropterus* by Schaefer and Marr (1948a), and there is only a remote possibility that they could be the juvenile form of another species or an unknown form. These specimens were taken by dip net under a night light and from the following localities: 5 specimens, 14 to 20 millimeters fork length, Minis Island, Pilas Island Group, Sulu Archipelago, 6°37.2′ N., 121°31′ E., May 7, 1948; 13 specimens, 9.8 to 35 mm. fork length, Davao Gulf, Mindanao, 6°44.5′ N., 125°36.7′ E., May 13, 1948.

The species can be roughly identified in the field by the entirely black first dorsal and by the relatively deep, heavy body. Figures 1 through 5 show these characters at several stages of growth. The second dorsal remains colorless until the fish reaches a length of about 25 mm. At this stage the basal half of the fin develops a light brown pigmentation which becomes progressively darker as the fish grows larger.

The smallest specimen in the collection (9.8 mm.) is colorless except for an entirely black first dorsal and, just anterior to the nape, a dark brown subcutaneous area of pigment on the dorsal aspect of the head that also covers the brain. The body is lightly pigmented anteriorly and dorsally at about

15 mm., the color lighter on the sides. The head remains colorless, except for the subcutaneous area of pigment covering the brain and a few pigment spots at the tip of the snout. As the size increases, the nape, operculum, and posterior edge of the orbit become pigmented and darker. The body color becomes more pronounced and expands posteriorly as the fish grows larger, finally covering most of the dorsal and lateral surfaces to the midline of the sides. A horizontal stripe of darker pigment extends backward along the midline of the side, and is separated from the brown dorsal area by a narrow band of lighter pigmentation. In specimens of about 28 mm. there are traces of several dark, wide, vertical bars beginning to develop. These extend downward from the dorsal midline and become fainter laterally. The largest specimen in the collection (35 mm.) has 5 well-defined, dark, vertical bands.

The first dorsal had 14 spines in all specimens examined. The first spine in the smaller specimens is slightly longer or equal to the second, and equal to the second in the larger specimens. The last spine of the first dorsal almost reaches the base of the second dorsal. The combined count of the rays and finlets of the second dorsal is 22 or 23 (23 in three specimens), with 14 or 15 rays and 8 finlets.

There are 14 anal rays and 8 finlets present, with a combined count of 22. The finlets are completely

FIGURE 1.—Juvenile *Neothunnus macropterus*. Drawn from a specimen 9.4 mm. fork length.

united by interradial membranes in the smallest specimens. As the size increases, these membranes become reduced and in the largest specimens only a partial membrane connects the posterior edge of each finlet to the base of the following finlet. Pectoral rays vary from 21 in the smallest specimen to 32 in the largest, increasing in number as the fish develops.

It is difficult to distinguish between the last fin ray and the first finlet in the smaller specimens, but they are easily separated in larger specimens. The rays and the finlets differ in general appearance. Each finlet is branched distally and the branches are flattened and widely spread, which gives the outer end of the finlet a leaf-like appearance. The fin rays also are branched, but do not exhibit the flattened, spread, leaf-like appearance of the finlet. The branches of each ray remain rounded, except perhaps at the very tip where they may be slightly flattened. There is also a difference in the manner in which the rays and finlets are united to their bases. The finlets appear to set on a peduncle or base, and the basal part of the finlet almost reaches to the surface of the body. The fin rays on the other

FIGURE 2.—Juvenile *Neothunnus macropterus*. Drawn from a specimen 16.5 mm. fork length.

hand, extend into the body and there is no indication of the union of the ray with its base.

There are 28 to 30 maxillary teeth on each side of the upper jaw, and 34 to 36 teeth on each side of the mandible or lower jaw. Palatine teeth are present, 12 to 14 on each side, and arranged in two irregular rows anteriorly, tapering to a single row posteriorly. Vomerine teeth are present.

The gill rakers in specimens of 16 mm. are merely minute projections, with a count of 3+1+11. In specimens of about 25 mm. fork length the count is 5+1+18 and in the largest example it is 7+1+20. The gill-raker count of adult *N. macropterus* is 7–9+1+19–22. Three large spines are present at the angle of the preoperculum in the smallest specimen. There are also two smaller spines along the vertical edge of the preoperculum and three along the lower horizontal edge. As the fish grows larger these spines become embedded in the developing preopercular bone and finally disappear. The largest specimen in the collection has only the tips of the spines at the preopercular angle still protruding from the edge of the bony deposit. When viewed by transmitted light the rest of the spines can be faintly seen embedded in the preopercular bone. The anterior portion of the lateral line is barely visible above the pectoral fin and has the

usual abrupt arch characteristic of the family Thunnidae.

The intestine lies along the right side of the body cavity and in the 35 mm. specimen there is a sharp S-shaped curve, which is the beginning of the formation of the intestinal folds. The right lobe of the liver is larger than the almost equally sized center and left lobes.

Two specimens, 16.5 and 28 mm. fork length, respectively, were cleared and stained according to the method used by Hollister (1934). The total vertebral count on each specimen was 39. There were 18 precaudal and 21 caudal vertebrae. No attempt was made to study in detail the structure of the vertebral column. The first closed haemal arch could not be exactly determined, but appeared to be either on the tenth or eleventh vertebra. The number of vertebrae (18+21=39), the shape of the anterior portion of the lateral line, and the beginning of intestinal folds place these specimens in the family Thunnidae as defined by Kishinouye (1923).

It is much more difficult to make the generic and specific determinations, and these cannot be settled with certainty until a complete collection of the juveniles of all the species of Thunnidae occurring in the Philippines has been made. Five species of this family have been recorded from Philippine waters: *Thunnus orientalis*, *Thunnus germo*, *Parathunnus mebachi*, *Kishinouella tonggol*, and *Neothunnus macropterus*. The first three species are rarely taken in Philippine waters, the fourth is common, and the fifth, abundant. An unidentified species of tuna has been reported from southern Mindanao by Domantay (1940), but no further information is available. No unknown species have been seen or collected by the biologists of the Philippine Fishery Program.

The black tuna, *T. orientalis*, is closely related or perhaps identical with the bluefin tuna, *T. thynnus*, of the west coast of North America and the Atlantic Ocean, but no effort has been made here to clarify its systematic position. The only records of this species from the Philippines were made by Dr. Albert W. Herre [3] between 1925 and 1940. Either it was observed by him or reported to him that this species was present in the Gulf of Davao, off the southeastern coast of Mindanao, and in the South China Sea off Lubang Island. As none has been seen or reported in almost two years' field work by biologists of the Philippine Fishery Program, *orientalis* is evidently extremely rare. Prior to World War II the Japanese carried on a long-line fishery for this species between Formosa and northern Luzon in the late winter and early spring months. The fish caught were large (100 to 450 pounds), and taken in depths of 25 to 30 fathoms. It seems probable that the Philippine records were also taken from deep water, as the Japanese carried on a small long-line fishery in the Davao Gulf and southeastern Mindanao prior to the war, and they also fished for tuna by deep hand lines around Lubang Island. Herre gives no indication of the abundance of this species, but it is assumed that it is extremely rare, as no other records are available.

Kishinouye (1923) reported the range of water temperatures inhabited by *T. orientalis* to be 5° to 20° C. and the optimum temperature from 10° to 15° C. Water temperatures recorded by the oceanographic studies of the Philippine Fishery Program in the Gulf of Davao and southeastern Mindanao are 27° C. on the surface and at 50 meters; 15° C. at 200 meters; and 10° C. at 350 meters. The temperature of the ocean is somewhat lower off Lubang

[3] Unpublished manuscript, Check List of Philippine Fishes.

FIGURE 3.—Juvenile *Neothunnus macropterus*. Drawn from a specimen 23 mm. fork length.

Island, being 22° C. at 50 meters; 15° C. at 175 meters; and 10° C. at 375 meters. A further decline is recorded from northern Luzon where the temperature is 21° C. at 50 meters; 15° C. at 150 to 175 meters; and 10° C. at 350 meters. In the Sulu Sea the temperature is 28° to 30° C. at 50 meters; 15° C. at 200 meters; and 10° C. at 800 meters. If Kishinouye's observations regarding the range of temperature for this species are significant, it seems probable that the northern Philippines represent the southern limit of the regular range of black tuna, and the other records are of fish that have strayed beyond their normal habitat.

Kishinouye (1923) was of the opinion that *T. orientalis* spawns in Japanese offshore waters, as he found black tuna with greatly enlarged gonads there during June and July, and spent gonads in August. Inasmuch as most Philippine waters have temperatures above the indicated range for this species and as there are indications that it spawns in more northern waters, in all probability the juveniles found in Philippine waters would not be *orientalis*.

The albacore, *Thunnus germo*, has been reported from the Philippines by Seale (1908), Villadolid (1937), and Herre (in manuscript). In 1937 a single specimen was identified and sent to the Philippine Bureau of Science by Agustin F. Umali, of the Philippine Bureau of Fisheries, where the identification was confirmed by the museum authorities. This specimen was destroyed during the liberation of Manila in 1945. Umali reports that there were six albacore in the public market at Naga, Luzon, where he secured the specimen and that they were caught by hand line in 100 to 120 fathoms of water. This species seems of irregular occurrence in Philippine waters, as there are no indications of its capture by prewar Japanese long-line fishermen in or near the Philippines, although it was caught commercially in small numbers in the former Japanese-mandated islands. The range of water temperature for albacore was reported by Kishinouye (1923) to be 10° to 25° C., which is at, or largely below, the temperature range of most Philippine waters. No information is available as to the location or time of spawning, but this species is believed to spawn in the open ocean. In view of its extreme rarity and the fact that it seems to be almost entirely oceanic in habit, young tuna found in Philippine waters most likely do not belong to this species.

There is a single record of the big-eyed tuna, *Parathunnus mebachi*, from the Philippines. This was made by Domantay and Herre in 1940 from the Sulu Sea, near Zamboanga, Mindanao, and recorded by the latter in his Check List of Philippine Fishes. The apparent scarcity of this tuna would make doubtful the presence of juvenile fish of this species in Philippine waters. Also, the 9 dorsal and anal finlets of the big-eyed tuna further separate the specimens at hand from it.

The least tuna, *Kishinouella tonggol*, is commonly found in Philippine waters at certain seasons although seemingly not nearly so abundant as the yellowfin. It is the only other species of Thunnidae in these waters the juveniles of which are likely to be represented in the collections of the Philippine Fishery Program, as specimens approaching maturity have been taken by trolling from the *Spencer F. Baird*. However, the gill-raker count of 5–6+1+16–17 for adult *K. tonggol* would eliminate it inasmuch as the larger juveniles of *N. macropterus* already have a greater number of gill rakers than is present in the adult least tuna. This evidence,

FIGURE 4.—Juvenile *Neothunnus macropterus*. Drawn from a specimen 27 mm. fork length.

FIGURE 5.—Juvenile *Neothunnus macropterus*. Drawn from a specimen 37.5 mm. fork length.

although slight, seems to eliminate the possibility that the juvenile specimens in the collections which have been assigned to *N. macropterus* could be *K. tonggol.*

KATSUWONUS PELAMIS (LINNAEUS)

Six specimens, identified as *Katsuwonus pelamis*, were taken in the following locality: 6 specimens, 13 to 27 mm. fork length, Minis Island, Pilas Island Group, Sulu Archipelago, 6°37.2′ N., 121°31′ E., May 7, 1948, night light, *Spencer F. Baird.* These specimens agree with the description of *K. pelamis* as given by Schaefer and Marr (1948a) for the juvenile forms from the west coast of Central America.

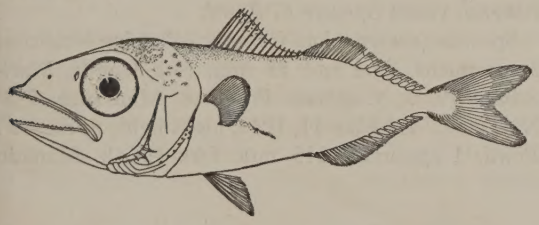

FIGURE 6.—Juvenile *Katsuwonus pelamis*. Drawn from a specimen 13 mm. fork length.

The 13 mm. specimen (fig. 6) is almost entirely colorless, the light brown color being confined to the anterior portion of the dorsal surface of the body and to the brown subcutaneous pigmentation covering the brain. There is a slight trace of color on the distal portion of the first dorsal. The largest specimen illustrated in figure 9 is lightly and evenly pigmented over the entire dorsal aspect of the body. Laterally, the color becomes lighter then abruptly darkens, forming a dark longitudinal band along the midline of the sides. The nape, operculum, and posterior margin of orbit are light brown. The tip of the snout, maxillary, and anterior half of the mandible are lightly pigmented. The first dorsal is irregularly patterned distally with light brown, but is colorless on the basal half. No traces of

FIGURE 7.—Juvenile *Katsuwonus pelamis*. Drawn from a specimen 18 mm. fork length.

darker vertical bars are present in any of the available specimens.

There are two large spines at the angle of the preoperculum. In the smallest specimen there are, in addition, three small spines along the vertical edge of the preoperculum, and four along the ventral edge. As the fish increases in size bone is deposited between these spines which gradually disappear. In the largest specimen only the tips of the two large spines are plainly visible, but traces of additional spines can be seen when viewed by transmitted light.

The first dorsal has 16 spines, and the last spine almost reaches the base of the second dorsal. There is a total count of 22 or 23 (22 in one specimen) second dorsal rays and finlets. Although difficult to count accurately in the smaller specimens, there are 15 rays and 7 or 8 finlets (7 in one specimen).

FIGURE 8.—Juvenile *Katsuwonus pelamis*. Drawn from a specimen 24 mm. fork length.

The dorsal finlets are united by interradial membranes in the smaller fish. This membrane is reduced as the fish grows larger, and in the largest specimen the membrane joins the posterior outer edge of each finlet with the base of the following finlet. The total count of anal rays and finlets is 21 or 22 (mostly 22). A single specimen has 14 rays and 7 finlets and the rest have 15 rays and 7 finlets. The number of pectoral rays varies according to the size of the specimen and no count was made.

On the largest specimen the gill-raker count is 2+1+22. Only small projections are developed on the upper angle of the gill arch and the ventral one-third of the lower angle has not as yet developed gill rakers. Gill rakers were not counted on the smaller specimens. Maxillary teeth are about 21 on each side of the upper jaw; and mandibular teeth, about 26 on each side of the lower jaw. Palatine teeth are present and about 8 in number. Vomerine teeth are absent.

The vertebrae were counted in the 27 mm. specimen which was cleared and stained with alizarin red S. There were 20 precaudal and 21 caudal vertebrae for a total of 41. The "trellis" of Kishinouye (1923) was beginning to form although not completely unified. The first closed haemal arch was on the twelfth vertebra.

The structure of the vertebral column identifies these specimens with the family Katsuwonidae as described by Kishinouye and the vertebral count of 20+21 identifies them as *Katsuwonus pelamis*. The specimens also agree in other characters with the description of this species as given by Schaefer and Marr (1948a).

EUTHYNNUS YAITO (KISHINOUYE)

Thirty-eight of the 40 juvenile specimens identified as *Euthynnus yaito* were found in the public markets of Batangas, Batangas Province, Luzon; Taal, Batangas Province, Luzon; and Manado, Celebes, Netherlands East Indies. The remaining two specimens were taken under a night light aboard the research vessel *Spencer F. Baird*.

Specimens were taken from the following localities: 2 specimens, 33.5 and 35 mm. fork length, Marigabato Point, Cotabato Province, Mindanao, 7°2′ N., 124°12′ E., May 11, 1948, night light, *Spencer F. Baird;* 1 specimen, 115 mm. fork length, Manado

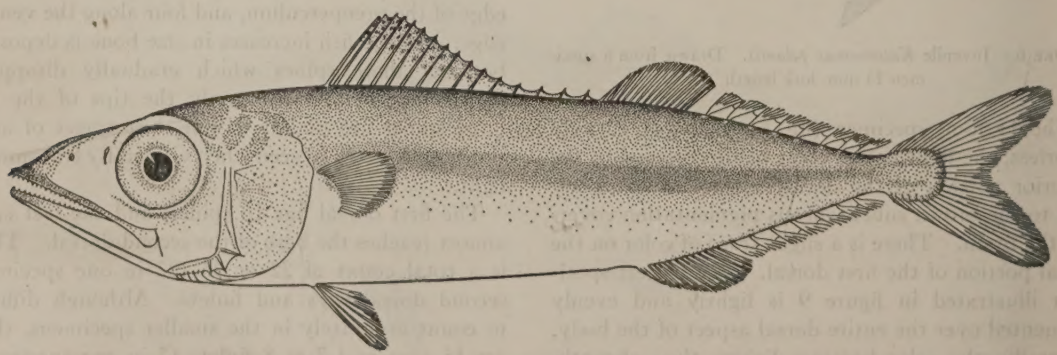

FIGURE 9.—Juvenile *Katsuwonus pelamis*. Drawn from a specimen 27 mm. fork length.

FIGURE 10.—Juvenile *Euthynnus yaito*. Drawn from a specimen 33.5 mm. fork length.

Public Market, Manado, Celebes, Netherlands East Indies, March 6, 1948; 7 specimens, 143 to 178 mm. fork length, Batangas Market, Batangas, Luzon, April 20, 1948; 4 specimens, 127 to 175 mm. fork length, Taal, Batangas Province, Luzon, May 10, 1948; 2 specimens, 40 and 44 mm. fork length, Batangas Market, Batangas, Luzon, May 17, 1948; 2 specimens, 40 and 68.4 mm. fork length, Batangas Market, Batangas, Luzon, March 12, 1949; 1 specimen, 80 mm. fork length, Batangas Market, Batangas, Luzon, March 28, 1949; 1 specimen, 76.5 mm. fork length, Batangas Market, Batangas, Luzon, April 20, 1949; 18 specimens, 73 to 112 mm. fork length, Batangas Market, Batangas, Luzon, April 25, 1949; 2 specimens, 117.5 and 131 mm. fork length, Batangas Market, Batangas, Luzon, April 27, 1949.

The body of small specimens is light brown dorsally (fig. 10), becomes paler laterally toward the midline of the side, and a dark longitudinal band occurs along the midline of the side. The body is pale ventrally and the pigmentation extends only slightly below the midline of the sides. The first dorsal is uniformly dark brown for the first three or four anterior spines. On the remaining spines the dark color is confined to the distal margin of the fin and approaches the base only near the posterior spine. Basally, the rest of the fin varies from almost entirely colorless to a light brown. The first dorsal is never uniformly colored and the other fins are colorless. The head is lightly colored with dark areas on the nape, operculum, and anterior half of the snout. There is a conspicuous crescent-shaped, light area behind the eye.

The body color and the head darken as the fish grows larger, as shown in figures 10 to 13. From 9 to 13 darker vertical bars begin to develop dorsally on the body at about 60 mm. fork length. These bars extend downward on the sides, becoming lighter laterally. In some specimens they reach only to the midline of the sides, while in others they extend well below the midline. These vertical bars are present on the largest specimens (68 to 178 mm.) in the collection. The head becomes almost uniformly dark except for a light area posterior to the eye. The first dorsal retains the color pattern of the smaller specimens. The anterior spines and the tips of the posterior spines are dark brown, and the basal part of the fin is lighter in color. The second dorsal is lightly pigmented on the basal half of the fin at

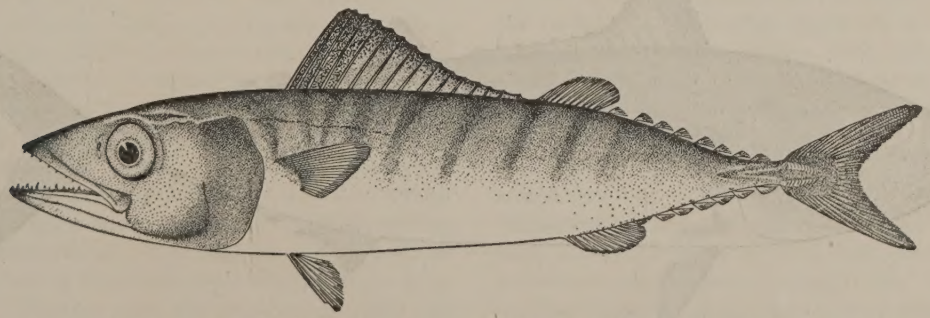

FIGURE 11.—Juvenile *Euthynnus yaito*. Drawn from a specimen 67 mm. fork length.

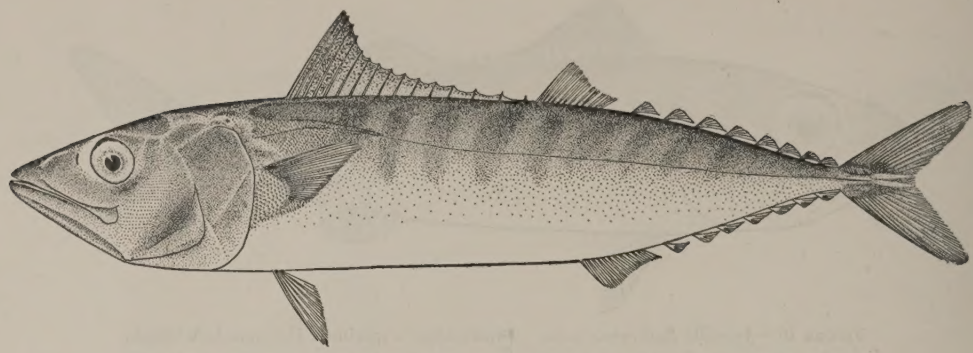

FIGURE 12.—Juvenile *Euthynnus yaito*. Drawn from a specimen 110 mm. fork length.

about 70 mm. and becomes slightly darker as the fish grows larger. Pectoral and caudal fins are progressively more pigmented as the size increases. The remaining fins are colorless.

There are 16 spines in the first dorsal and the posterior spine almost reaches the base of the second dorsal. The second dorsal has 12 to 14 rays (mostly 13) and 8 finlets. The anal fin has 13 or 14 rays (13 in one specimen) and 7 anal finlets. In the smallest specimens the interradial membrane partly connects the finlets. This connecting membrane has almost disappeared by the time the fish is 70 mm. in length, and is absent in the large specimens.

The gill rakers are small and difficult to count in the smaller specimens, and the full complement has not yet developed. The gill-raker count on a 35 mm. specimen was 4+1+20, increasing to 7–8+1+22–23 in specimens of 127 to 175 mm.

A vertebral count was made on a 44 mm. specimen which was cleared and stained in alizarin red S. The vertebrae totaled 39, with 20 precaudal and 19 caudal. The first closed haemal arch was either on the 15th or 16th vertebra, but its exact position could not be determined without dissection, which was not desirable. It appeared either to be closed or the ends of the haemal spines were lying close together on the 15th vertebra, but the haemal arch on the 16th vertebra was definitely closed. Inferior foramina are present on the posterior precaudal and about 10 anterior caudal vertebrae. The lateral processes of the posterior caudal vertebrae were beginning to develop.

The maxillary and mandible have about 35 small, pointed teeth in a single row on each side of the upper and lower jaws. Palatine teeth are present in a single row of 11 to 13 small, pointed teeth. Vomerine teeth, 4 or 5 in number, are small and easily overlooked. In the two smallest specimens there are traces of two spines at the angle of the preoperculum. In the larger specimens bone has completely covered the spines which can no longer be seen.

The intestine lies along the right side of the abdominal cavity, and is fairly straight and not

FIGURE 13.—Juvenile *Euthynnus yaito*. Drawn from a specimen 156 mm. fork length.

folded. The liver has three lobes of which the right lobe is by far the longest.

These specimens have the number of vertebrae and the complex vertebral structure called a "trellis" which are characteristic of the Katsuwonidae as defined by Kishinouye (1923). Within this family the elongated right lobe of the liver and the posterior position of the first closed haemal arch correspond to previous descriptions of the genus *Euthynnus* (Kishinouye 1923; Schaefer and Marr 1948b), in which these specimens are placed.

Kishinouye (1919) described a second species, *Euthynnus lineatus*, from Manzanillo, Mexico. His description was based upon a single specimen, which was separated from *E. yaito* mainly by its coloration and the size of the head. The juvenile forms of *E. lineatus* have recently been described by Schaefer and Marr (1948b). Comparison of their description with the present specimens shows several consistent differences, principally in the vertebral and gill-raker counts, color pattern, and the slightly greater number of dorsal spines and rays and anal rays in *E. yaito*.

There are usually 37 vertebrae in *E. lineatus*, although occasionally there may be 39. Juvenile *E. yaito* from the Philippines had a vertebral count of 39 in the specimens examined. Too little material of both species has been studied to define accurately the vertebral count, but there seems consistently to be a difference of two vertebrae in the two species.

There are fewer gill rakers on the first gill arch of *E. yaito* than on that of *E. lineatus*. Philippine specimens of *yaito* have a total count of 31 or 32 gill rakers, and *lineatus* about 38. The gill rakers of 35 adult *E. yaito* were counted and they varied from 29 to 33 (mostly 30 to 31), which is the same as in the larger juveniles.

There were 16 spines in the first dorsal of the specimens of *E. yaito* examined; 15 and occasionally 14 have been described for *E. lineatus*. According to Kishinouye (1923) the first dorsal of *yaito* has 15 to 16 spines, but no juvenile specimens were found with 15 spines in the present study. There are 13 rays in the second dorsal of the Philippine specimens instead of the 12 present in *lineatus*. Kishinouye gave the second dorsal ray count as 12 to 13 for *yaito*, but again none was found with 12 rays in these investigations. The anal rays of *yaito* numbered 14, rarely 13 as compared with the 11 or 12 of *lineatus*. Thirteen was the number of anal rays given for *yaito* by Kishinouye. The dorsal and anal fin ray counts of *E. yaito* were generally at the upper limits of the counts given by Kishinouye for this species. Statistical treatment of a large series of both species may show significant differences in fin ray counts.

There are certain differences between the color patterns of the two species that seem characteristic. Schaefer and Marr (1948b) reported that the entire first dorsal of *E. lineatus* was heavily pigmented in all specimens studied by them. In Philippine specimens of *E. yaito* the heavy pigment is confined to the anterior part of the fin and to the outer ends of the posterior spines; and the basal part of the remainder of the fin is either almost colorless or lighter in color than the distal. The basal half of the second dorsal is less heavily pigmented, and there is no conspicuous series of dark spots along the anal base or on the following finlets. The vertical bars are more numerous in *E. yaito* and persist until the fish reaches a larger size. There is a pronounced pale, crescent-shaped area behind the eye of *yaito* which is not evident in *lineatus*.

SPAWNING AREAS

The finding of juvenile forms of *Neothunnus macropterus*, *Katsuwonus pelamis*, and *Euthynnus yaito*, three species of tunas inhabiting Philippine waters, has determined several probable spawning areas for these fish. In addition, the juvenile forms of two species of the genus *Auxis*, previously described by Wade (1949), have been taken in the same localities and presumably spawning by those species occurs there.

Juvenile yellowfin tuna, *N. macropterus*, were collected from the Davao Gulf, Mindanao, and at Pilas Island, Sulu Archipelago, near Zamboanga, Mindanao. These two areas are some 250 to 300 miles apart. Davao Gulf is located at the southeastern corner of Mindanao, and Pilas Island is south of the tip of the Zamboanga Peninsula at the southwestern end. All specimens were secured during the first half of May 1949, and the small size of the specimens would indicate that spawning took place the preceding month.

A spawning area for the striped tuna was also established at Pilas Island, Sulu Archipelago, Mindanao. The specimens secured in that area were small and probably were spawned the month previous to their capture in May 1948.

Three spawning areas were located for *Euthynnus yaito*. A single specimen, taken from the south-

eastern part of the Celebes Sea, was found in the market at Manado, Celebes. This specimen was 115 mm. fork length and probably was three or four months old at the time of its capture in March 1948. Two small specimens were taken from the Moro Gulf at Marigabato Point, Cotabato Province, Mindanao, in May 1948. These specimens probably were spawned the month before they were captured. The greatest number of juvenile *E. yaito* were collected at Batangas, Batangas Province, Luzon, where thirty-seven specimens ranging in length from 40 to 175 mm. fork length were secured during March, April, and May of 1948 and 1949. The range in size indicates that some may have been spawned as long as six months before their capture and that the spawning season in this locality extends over a 4- to 6-month period. The specimens collected at Batangas came from the commercial fisheries of Batangas and Balayan Bays. Both of these bays are large and open, and freely accessible to the sea. It appears certain that this species spawns in or near both of these bays. The young of *E. yaito* come into the markets mixed with catches of Engraulidae, Clupeidae, and other small fishes which are caught in fish traps along the shore, or by beach seines and round haul nets.

It should be realized that the present knowledge of the several spawning areas is based primarily upon the results of exploratory operations over a large area and that additional intensive research in the future will undoubtedly extend the known spawning areas of these species. It is probable that all the southern half of Philippine waters and much of the northern half will be found to be the spawning grounds of several species of tuna.

SUMMARY

Several juvenile stages of three species of tuna living in Philippine waters were collected by means of night lights and market studies. Two species, *Neothunnus macropterus* and *Katsuwonus pelamis*, were found entirely in night light collections and the third, *Euthynnus yaito*, was taken mainly from the commercial catch of small fishes found in the public markets.

Both *Neothunnus macropterus* and *Katsuwonus pelamis* agree with Schaefer and Marr's (1948a) description of the juveniles of these species collected off the west coast of Central America. Philippine specimens of *Euthynnus yaito* differ from *E. lineatus* of the eastern Pacific and agree more closely with Kishinouye's (1923) description of *E. yaito* from Japanese waters.

On the basis of the present collection of juvenile forms, possible spawning localities for several species of tuna can be designated. Spawning areas for *N. macropterus* possibly occur in Davao Gulf, Mindanao, and at Pilas Island, Sulu Archipelago. A spawning locality was established for *Katsuwonus pelamis* at Pilas Island, Sulu Archipelago. There is evidence that the bonito, *Euthynnus yaito*, may spawn in the vicinity of Manado, Celebes, Netherlands East Indies; Marigabato Point, Cotabato Province, Mindanao; and Batangas and Balayan Bays, Luzon.

LITERATURE CITED

Domantay, Jose S.
1940. Tuna fishing in southern Mindanao. Philippine Jour. Sci., vol. 73, No. 4, pp. 423–434, pls. 1–9.

Hollister, Gloria.
1934. Clearing and dyeing fish for bone study. Zoologica, vol. 12, No. 10, pp. 89–101.

Kishinouye, Kamakichi.
1919. *Euthynnus yaito* produced in Mexico. Proc. Sci. Fisheries Assoc., Imperial Univ., Tokyo, vol. 3, No. 2, p. 113.
1923. Contributions to the comparative study of the so-called scombroid fishes. Jour. College of Agric. Imp. Univ., Tokyo, vol. 8, No. 3, pp. 293–475. 26 figs.

Lütken, Charles.
1880. Spolia atlantica. Bidrag til Kundskab om Formforandringer hos fiske under deres vaext og udvikling, saerligt hos nogle af atlanterhavets højsøfiske. Vidensk. selsk. skr., 5. Raekke, naturvidenskabelig og mathematisk afd., vol. 12, No. 6, pp. 413–613.

Marr, John C.
1948. Observations on the spawning of the oceanic skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Neothunnus macropterus*) in the northern Marshall Islands. U. S. Fish and Wildlife Service, Fishery Bull. 44, pp. 201–206.

Schaefer, Milner B. and Marr, John C.
1948a. Spawning of yellowfin tuna (*Neothunnus macropterus*) and skipjack (*Katsuwonus pelamis*) in the Pacific Ocean off Central America, with descriptions of juveniles. U. S. Fish and Wildlife Service, Fishery Bull. 44, pp. 187–196.
1948b. Juvenile *Euthynnus lineatus* and *Auxis thazard* from the Pacific Ocean off Central America. Pacific Science, vol. 2, No. 4, pp. 262–271. 4 figs.

Seale, Alvin.
1908. The fisheries resources of the Philippine Islands. Part I, Commercial fishes. Philippine Jour. Sci., vol. 3a, pp. 513–529.

Villadolid, Deogracias V.
1937. The fisheries of Lake Taal, Pansipit River, and Balayan Bay, Batangas Province, Luzon. Philippine Jour. Sci., vol. 63, No. 2, pp. 191–225, pls. 1–4.

Wade, Charles B.
1949. Notes on the Philippine Frigate Mackerels, Family Thunnidae, Genus *Auxis*. U. S. Fish and Wildlife Service, Fishery Bull. 46, pp. 229–240.

UNITED STATES GOVERNMENT PRINTING OFFICE : WASHINGTON : 1950

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. - Price 10 cents

DESCRIPTION OF A PROJECTION DEVICE FOR USE IN AGE DETERMINATION FROM FISH SCALES

By KENNETH H. MOSHER, Aquatic Biologist

Many scale reading devices of varied design have been reported by workers engaged in fishery research, however, most of those described or used have had serious disadvantages affecting the ease of operation or the accuracy of the results obtained. Consequently, it appears useful to describe in detail the instrument which has proved very satisfactory in the study of the ages of the California sardine or pilchard. The original unit was developed in 1938 and 1939 concurrently with the investigation of the readability of the sardine scales and otoliths by the Fish and Wildlife Service in California. This instrument was a major factor in the development of a successful method of determining age from the difficult markings on the scales of this species.

The original instrument has been substantially improved from time to time by the addition of certain refinements to provide a clearer image and brighter field. During the course of the sardine program, similar instruments were constructed for workers in Monterey and Terminal Island, Calif. so that at present there are three such units in use on the sardine studies, each calibrated to the same magnification.

The success achieved with this apparatus in determining the age of the sardine sugested its suitability for age determination in other species.

The instrument described in the following paragraphs was constructed by the author at the Seattle Laboratory for the Alaska Fishery Investigations for age determination of salmon and herring. It has been patterned after the one in use in the sardine investigation.

The unit consists essentially of a microscope of suitable power; a 90° prism ½ to ¾ inch long, silvered on the largest face; an 8- by 10-inch plate glass mirror; a piece of white celluloid or white paper upon which the image is projected; and a suitable light source. When a large number of scales are to be examined, it is desirable to equip the microscope with a mechanical stage in order to bring the various scales rapidly and precisely into the field of the objective.

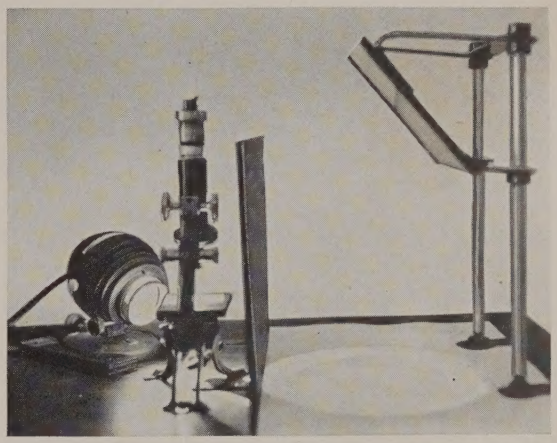

FIGURE 1.—Microprojector in operation, viewed from the operator's position. Note location of the controls of the microscope and lamp in relation to the projected image.

The proper magnification of the adult salmon scales which are approximately 4 to 8 mm. in diameter requires the use of a 40-mm. objective with a 6-power eyepiece, or equivalent. Using a 25-mm. objective with the same ocular gives a satisfactory image for use with the 1- to 3-mm. diameter scales of juvenile salmon. For larger scales such as herring and sardines, a lower power of ocular or objective, or both, will be required. The optimum magnification to use with any particular fish scale can best be determined through experiment, keeping in mind that too great a magnification tends to enlarge the details of the scale surface to the point where they obscure the annular marks and too small magnification will not reveal the annuli clearly. There is a relatively narrow range of magnifications wherein the annuli appear to the best advantage. For most scales examined, the optimum results were obtained when the projected image of the sculptured portion was around 150 mm.

Any microscope of the desired power with corrected optical parts will be adequate for this purpose. Coated optics in a double or triple nosepiece, fine adjustment, condenser, iris diaphragm, and mechanical stage will prove convenient but are not essential to satisfactory operation of the instrument. The microscope incorporated into the present unit is an old one, but the results have been very satisfactory. A good plate-glass mirror is required. A common glass mirror should not be used as the flaws will cause severe distortions which will render the unit inaccurate for measurement of the image. On the other hand, more expensive types, such as the first-surface ophthalmic mirrors, have been tried with the conclusion that they are not superior to those of plate glass. The light source is one of the most important items in the projector. It must provide a bright, clear light with a flat field. The best lamps for this purpose are some of the newer types designed for microprojection.

In constructing the device, a piece of ⅝- to ¾-inch plywood, approximately 18 by 36 inches is required for the base. Two metal rods or pipes ½ to 1 inch in diameter are needed to support the mirror at the proper angle and height above the base. In the present unit this support is furnished by brass rods ⅝ by 18 inches, threaded for about 2½ inches on one end. These fit into two ⅝-inch holes drilled in the plywood base about 9 inches apart and a few inches from the right end. They are securely fastened by the use of washers and nuts.

A holder for the mirror was made from 20-gauge brass, held at the proper angle to the supports by ⅛- by 1½-inch brass straps. The mirror holder could be made of a variety of materials such as wood, plastic, or metal. The important consideration is that the mirror be held rigidly at a 45° angle to the base and at the same time be adjustable up and down on the supports in order to center the image for the height of the microscope used. In this instrument the holder is locked firmly in any desired position by means of set screws in metal collars. Once the holder is set up and adjusted for a particular microscope, it will not be necessary to change the adjustment. When the mirror has been firmly set in place, the microscope should be placed about 15 or 16 inches to the left side of the mirror. This is the most satisfactory arrangement for a right-handed person, as focusing can be done with the left hand, leaving the right hand free for the recording of data.

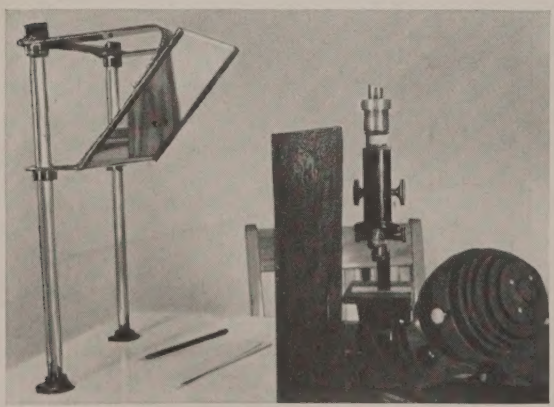

FIGURE 2.—Microprojection set-up. Illustrates the relation of parts to operator's position. Viewed from the back of the device.

A holder for the prism can be devised easily from metal tubing, wire, plastic, or other material. The prism should fit directly on the ocular of the microscope and should be attached securely so as not to shake off or become out of alignment with the microscope and mirror. The lamp is then set so as to throw its light on the microscope mirror, and the whole unit adjusted by trial and error until the projected image is clear, distinct, and properly placed for most convenient observation. When the adjustment is complete, the various instruments should be fastened in place to avoid the need for subsequent readjustment.

For best results the projector should be used in a relatively dark room. A photographic dark room is most suitable, but if this is not available, sufficient darkness can be obtained by covering the windows with heavy black curtains while using the machine. Satisfactory conditions can also be obtained by placing a cardboard or plywood box over the working area of the projector. Such a cover, as well as all other parts of the unit, should be painted a dull black to prevent reflection of light. It will also prove advantageous to place a piece of ¼-inch plywood or heavy cardboard vertically at the microscope between it and the mirror, just high enough for the prism on top of the microscope to project over it. This also should be painted a dull black on both sides to prevent stray light-rays from hitting the projected image.

If the optical items are of good quality and the adjustments are accurate, there should be very little if any distortion of the image as it is moved from one side of the field to the other.

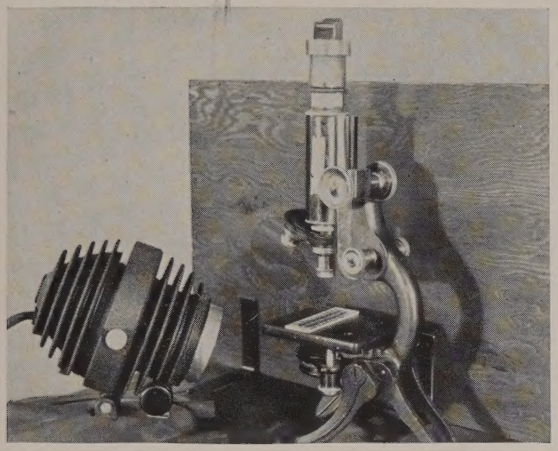

FIGURE 3.—Closeup of the microprojector, showing the relative position of the lamp, microscope, and prism. Viewed from a point to the left of the operator.

This projector can be assembled at relatively small cost, particularly if the microscope, with the necessary oculars and objectives, is on hand. The estimated cost of the prism at today's prices would be about $6 and that of the plate glass mirror about $1. The cost of miscellaneous material such as metal, plywood, washers, screws, nuts, collars, and paint is about $10; making the total outlay for accessory materials less than $20.

The advantages of this type of scale reader over the more conventional models are numerous and far outweigh the outlay of time and materials required for its construction. Advantages obtained through the use of this instrument are:

1. There is considerably less eyestrain with this unit than with direct examination of the scales through a microscope.
2. The image of the scale is clear and easily studied.
3. The image can be studied at a convenient level and in front of the operator with the controls at easy working distance.
4. The image can be measured, traced on paper, or photographed.
5. The image can be viewed by two or more workers at once which is very useful in the demonstration of scale reading, and also in arriving at proper interpretation of difficult scale markings.

The projection of the scale image provides objectivity in scale reading not ordinarily possible. Permanent records of all scales examined can be obtained by marking the base of the scale, the annuli, the margin, or other desired features on paper. These records can be used for the computation of lengths of fish at various ages, determination of growth rates, and for other purposes.

To facilitate statistical analysis it is suggested that punch cards containing a millimeter scale printed along one edge be used for recording the scale features. The "zero" mark of the ruler is placed at the base of the sculptured portion of the scale, or at the center of the nucleus, depending on the type of scale under study, and the annuli, scars, margin of the scale, and other data indicated by appropriate marks along the ruler. Data on time and locality of capture, sex, age, year class, etc., can be punched on the cards if desired. The data recorded on the cards will permit studies of such problems as racial composition, variations due to environmental factors, variations between year classes, and variations between readers, without further examination of the scales.

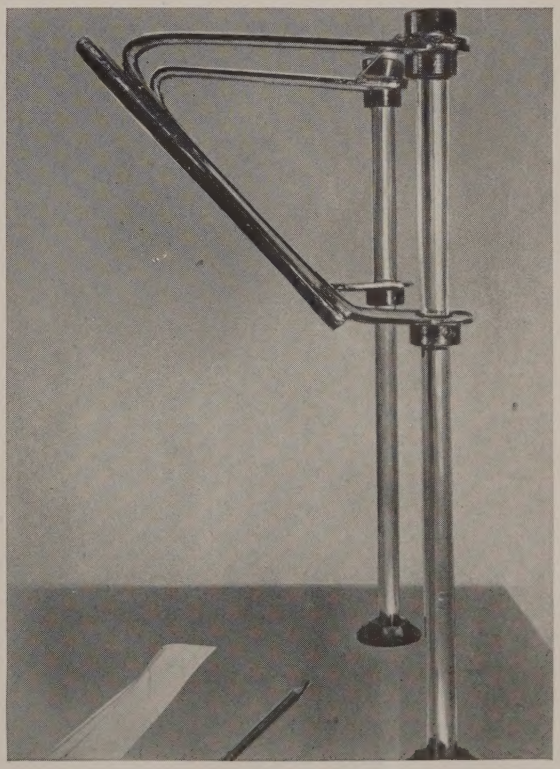

FIGURE 4.—Closeup of mirror and holder.